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"Lighter pressure with the second. Less subcutaneous and more cutaneous on the forefinger. Slow increase in intensity when the rod came down and quick decrease when the rod went up" (B). (5-3—) "Alternation of pressures quicker with the second than with the first. Less intense pressure with the second" (B). (2-3+) "A heavier pressure on the palm with the second. Slow alternation between the pressure on the finger and that on the thumb which gave the idea that the rod was hard to lift" (B). (3-2—) "First pressure was light and evenly distributed; second pressure at the base of the thumb was lighter" (F). (3-5—) "First pressure greater on the forefinger; second pressure lighter on the thumb" (F). (4-3—) "Pressure with the first was greater; no other difference" (F). (5-3) "With the up whip the pressure was more intense than in the second, but when the rods came down the intensity of the pressures was equal" (H). (2-3) "The immediate impression was one of slightly greater intensity on the forefinger with the second. When whipped the intensity became the same as the first" (H). (3-2) "First impression was 'shorter' but with the whip they became 'equal'. The pressure at the base of the thumb was, at first, weaker with the second but increased with whipping" (H). (3-1—) "The second experience seemed a little more diffuse but a little less extended. I did not notice any difference in intensity. It was more a judgment of inference than one of direct experience" (H).

Conclusions.—We conclude that the perception of the length of vertically whipped rods depends primarily upon the relative intensity of two opposed pressure experiences in the hand.

In addition, the most important items of experience for the perception and those which contribute most to its refinement are the differences in the frequency and rate of intensive changes with the whip.

The perception of difference in length correlates highly with difference in center of mass, and somewhat with difference in length of the stimuli.

LVII. ON THE NON-VISUAL PERCEPTION OF THE LENGTH OF HORIZONTALLY WHIPPED RODS

By A. S. BAKER

In every-day life the tools and instruments which we use move or act for the most part in the vertical plane; moreover, if one gives a rod to a blind-folded subject and asks him to judge its length, he will almost invariably whip it up and down. If, then, the perception is one in which the integration of the processes depends upon past experience, we should expect the perception of the length of a horizontally whipped rod to be less refined, less accurate in terms of stimulus, than that of the vertically whipped rod. On the other hand, since the psychophysical processes have a common origin and no new or lacking moment in the stimulus can be assumed *a priori*, we might expect the perception to be as accurately determined in the one case as in the other; the usual vertical whip being a muscular rather than a perceptual habit.

We did the experimental work for this study during the Summer term of 1921. The general procedure and apparatus were the same as in the preceding study by Shults.¹

¹Erna Shults, On the non-visual perception of the length of vertically whipped rods, *Amer. J. Psych.*, xxxiii, 1921, 135 ff.

The observers were Dr. H. G. Bishop (B), instructor in psychology; Dr. L. B. Hoisington (H), assistant professor of psychology; H. B. Kohlmeier (K) and C. N. Shlenker (S), juniors in the college of Arts and Sciences who had taken courses in general psychology. B and H were trained Os, H especially trained in this kind of observation; K and S were untrained.

The typewritten instructions were: "You will be presented with two rods in succession. You are to take them rather loosely in the hand and, after lifting them a short distance in the vertical plane, whip them back and forth twice in the horizontal plane. You will judge the *length* of the second in terms of the first, that is, you will judge the second as longer than, equal to, or shorter than the first."

The ordering of the stimulus moments resulted in a four-fold division of the experiment; Series I in which all moments varied, Series II in which length alone varied, Series III in which center of mass varied, and Series IV in which weight varied. In the last three series the other moments remained constant for all five stimuli. The standard rod was 85 cm. long, weighed 100 gr. and had its center of mass at 15 cm. out from the front of the handle. The increments and decrements of length were 5.5 and 11 cm., of weight 2 and 4 gr., and of center of mass 6 and 12 mm. In any series in which a given pair of moments were constant they were the same as those for the standard rod.

Quantitative Results.—Table I sums up the quantitative results as expressed in terms of h' and L' computed according to Urban from results got by the method of Constant Stimulus Differences.²

Apparently the most characteristic feature of this table is its lack of agreement between Os and more especially between the trained and untrained groups. All results agree, however, in that they gave the steepest curves or the largest values for h' in Series I, also that they gave no inversions of the first order for any O in this series. The results of B and H agree for Series IV in that they gave the smallest values for h' and both sets of results gave inversions of the first order. In fact, the results of H gave a negative value for L' for the judgment 'longer' as well as for the judgment 'shorter'; he tended to judge the heavy rods as shorter than the lighter ones. The small values of h' for the two trained Os show that weight conditioned the perception very little in Series I. The fact that difference in weight alone does not adequately condition the perception may not be accepted as proof that it might not be effective if given together with center of mass or with length. Time did not permit the further fractionation of moments; but Hoisington, in his analysis of the perception of lifted rods, found that weight and center of mass as co-variables gave no better ogive curves than did center of mass as sole variant. How far the two perceptions are analogous in this respect we cannot say. It is very doubtful whether the difference between the values of h' for Series I and III is due in any great measure to the elimination of differences of weight in the stimuli.

The results of H and S agree in that they gave the second largest values of h' for Series III; for S they are not much in excess of the values given in Series IV, for H they are very greatly in excess of those for Series IV and considerably greater than those for Series II. Although the results of B gave larger values of h' in Series II than in Series III for the judgment 'longer', the values for Series III are considerably greater than those for Series IV; the results of K for Series III gave the smallest values of h' for that O .

There can be but one conclusion: the Os were not doing the same thing, they were not judging under the same attitude. We naturally incline to give greater weight to the results of the practised Os. The stimulus factors

²For some remarks on this use of the values h' and L' see the preceding Study.

which condition the perception of the length of horizontally whipped rods are center of mass and length; weight touches off the meaning of length, given a length and a center of mass out beyond the hand, without conditioning the real perception of 'out there-ness'. This conclusion accords with the results of Hoisington³ and Shults.

The results of all *O*s gave fair values for *h'*, considerably larger than the values obtained by Shults and very much larger than those obtained by Hoisington, when length was the only variable. This result can not be explained on the ground of different *O*s, for H served in all three experiments. His results in the study by Hoisington gave for Series A V, which was in every way comparable with our Series II, the values of .054 and .046 for *h'* and of 12.7 and 14.2 for *L'* for the judgments 'longer' and 'shorter' respectively, and for Series II in the study by Shults the values of .286 and .157 for *h'* and of 2.25 and 2.69 for *L'* for the corresponding judgments. This seems due to a fact of inertia: in the present experiment the movement was at right angles to the direction of the force of gravity and, although the weight was the same for the long and the short rods and the center of mass was the same distance out from the hand, the greater extent beyond the center of mass resulted in a different stimulus-effect as *O* suddenly forced the rod into lateral motion. This explanation finds support in the results of H, who discovered that if he began the horizontal whip very slowly he did not perceive any difference in length between two rods for which he had clearly perceived a difference when he whipped them more quickly. Other *O*s, and especially B, remarked the same fact. H, therefore, repeated Series II and began the whip of the rods very slowly. The results gave .33 and .31 as values for *h'* and 2.0 and 2.1 as values for *L'* for the 'longer' and 'shorter' judgments respectively.

Qualitative Results.—The introspective reports show that a difference in the experience of *O* resulted when he whipped a long and a short rod; that the difference was in part of the same order as that experienced when the whipped rods showed differences in center of mass; and that it resembled in part those differences experienced with the primary perception of difference in length. The greater the inertia, the greater was the temporal lag and the greater were the pressures localized in the hand; whether the pressure at the back of the hand increased proportionately more than at the fore-finger is a question to which our *O*s did not return a positive answer. According to the principles of the lever we should expect the back pressure to increase relatively more than the fore if the applied power, in the form of inertia, came out along the rod.

B reports, for Series II, as follows. (5-3—) "The striking thing was that the pressures which were heavier, more massive and more intense with the first were lighter and less intense with the second, a light agile kind of pressure." (2-5+) "Condensation or intensification of pressure came up at the end of the swing, particularly at the back. With the second, a sort of intensification of the experience in general. Strain in hand more intense; some pressure in thumb and fingers." H reports: (2-5+) "More intense pressure with whip on the fore-finger and the pressure more widely distributed with the second. Also pressure of weak intensity in wrist and slowness of change in intensity with the second as compared to the first." (5-3—) "Intensity of pressure on fore-finger less with the second. Fluctuation of intensity with whip less with second but with a more rapid rise and fall of the intensity." (3-1—) "The clear difference in the two experiences was the slightly longer duration of the maximum intensity with the whip, a little greater spread of extent and a spatial shift of pressure on the thumb with the first." (5-2—) "Less intense pressure at base of thumb and less pres-

³L. B. Hoisington, On the Non-Visual Perception of the Length of Lifted Rods, *Amer. J. Psych.*, 1920, 31, 114-146.

sure in the wrist with the whip in the second. Fluctuations in intensity came more rapidly and the rise and fall of intensity was faster. Less extent with the second." K, who had visual imagery as part of almost every experience, reports: (1-3+) "Not much difference. Second stretched out farther in the field. Grey did not change. Fan larger in the second case. Pressure with first a slight bit less intense than with second." (5-3-) "Very noticeable difference. Pressure more intense with first; everything seemed more intense. Fan farther away, color brightened." S reports: (1-3+) "Pressure on fore-finger and in palm of hand, kind of jerky feeling with whip. Slight pressure in wrist; more intense with second." (5-3-) "Quite a good deal of pressure in wrist and fore-finger; increased intensity with the whip. Vibrations with the second fairly short. Little pressure except with whip, then pressure on little finger and back of hand; pressure shifted with opposite swing."

If we summarize all the reports for this series we find that the absolute intensity of the pressure experience, the amount and rate of intensive change, the rapidity with which the changes take place, the presence or absence of pressure and strain sensations in the hand, wrist and arm, the extent and the shift of localization of the pressure pattern, all serve as cues to give the meaning of difference of length. All these are in addition to the primary experience which carries the meaning of 'out there', viz., the experience of two opposed pressures which stand to each other in certain ratio-limits of intensity. These are additional modalities which enter into the total complex of experience when the rod swings back and forth in the horizontal plane; they modify the meaning of length, without being able, if they stand alone, either to carry the meaning of length, or in any way to originate the perception of length.

We have given first place in our discussion to the factor of differences in the length of the rods, because this evidently is a more important factor under these conditions than it was under the conditions of Hoisington or of Shults, although Shults found it somewhat effective. Difference in weight, as found in the previous Studies, does not condition the perception; under the conditions of the present Study it may and does, with the unpractised *Os*, touch off judgments of length in the same way as has been found by the previous workers in this field. The reports show that the bare increase of intensity of pressure does not enter into the 'length complex' in the same intimate way as do the modes of experience already mentioned.

A few reports from the practised and the unpractised groups will show the difference. (1-4=) "Intensity of pressures a little greater in the second. First, neutral pressure and contact in quality; second, a little more dull, draggy. The intensity of the fore and back pressures relatively equal in the two experiences; the temporal course was the same" (H). (4-2=) "Second much less intense as a whole than the first and a little less dull in quality. Slightly less extended. Temporal course the same" (H). (4-2=) "Pressure largely cutaneous. It was measured in terms of the 'throw' of the two sticks. Rotation in palm the same, which gave the basis for the judgment" (B). (1-4+) "Great difference, like wood and steel. Pressure with first much less intense than with second. Weight of first unnoticed; weight of second seemed 5 times that of first" (K). (5-3-) "First requires more pressure to hold in hand on both palm and fingers" (S).

Center of mass, also as in the previous Studies, stands out as the one moment of the stimulus which conditions the perception more than any other. The elements of experience were the same as in the list given above: more pressure and strain in the arm, wrist and hand; more extended pressures; absolutely greater but relatively less increase in intensity; slower alternation of maximum and minimum pressures; a slower rate of increase and decrease of intensity; more intensive pressures fore and back with the back pressure relatively more intense, and very often a shift in the local-

ization of the back pressure with the longer rods and the reverse with the shorter. The shorter rods pivoted at the back, and all the movement of the rod was forward from this point; the longer ones pivoted at the fore-finger, and the movement was both forward and back of this point.

B as well as K had visual images with almost every experience. At times they approximated to synaesthesia; it was as if the pressure came in visual terms. This makes it a little difficult to exhibit parallel cases from the reports of B. He reports: "Visual sensations of pressure, a sort of synaesthesia. Shifting pressure in hand correlated with visual streaks; as the pressure jumped up in intensity the grey became black." "Pressure sensations in wrist, fore-finger and palm. All these processes fuse somehow, and coupled with the visual experience give the basis for the judgment." "Pressure and visual experience combined again. No difference in visual terms between hand and stick. Spread out fan-shape, extended out in terms of visual process. The pressure seemed visible." In all this, however, as in the visual imagery of K, there is no sure evidence that the visual experience is any other than processes which accrue to the pressure experience in the hand and arm, and that it is at all essential to the perception of length cutaneously given.

Conclusions.—We conclude that the perception of the length of horizontally whipped rods is even more accurate than that for vertically whipped rods.

The perception depends primarily upon the presence in experience of two opposed pressures.

The presence, in the complex of experience, of pressures and strains in the arm and hand, of the shift of the pressure pattern in the hand, of differences in temporal formation, in extent and in intensity, all contribute to the perception.

We add that it is unwise to employ untrained observers in the study of a complex experience, when the period of training is necessarily short.